

Interactions between Vorticellids (Protozoa: Peritrichida) and Planktonic Algae in the Hawkesbury-Nepean River, New South Wales

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In 1991, during a summer bloom of *Melosira* (diatom) and *Microcystis* (cyanobacterium) in the Hawkesbury-Nepean River, vorticellids dominated the zooplankton. They attached to colonies and filaments of a variety of planktonic algae including *Melosira* and *Microcystis*. The number of vorticellids attached per substrate particle was low (mean 1-3 vorticellids). The observed vorticellids-planktonic algae interactions appear to be more commensal than proto-cooperative.

KEY WORDS: vorticellids, cyanobacteria, planktonic algae, Hawkesbury-Nepean River.

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INTRODUCTION

Frequent blooms of cyanobacteria are common in many overseas and Australian eutrophic waters (Reynolds, 1984; May, 1970; Heath and Cannon, 1990). Filaments and colonies of these cyanobacteria often provide substrates for the attachment of various bacteria, fungi, algae and protozoans (Canter *et al.* 1992 and references cited therein). In particular, infestation of cyanobacteria and other planktonic algae by vorticellids (Protozoa: Peritrichida) has been reported by Kerr (1983), Pratt and Rosen (1983) and Canter *et al.* (1992). Canter *et al.* (1990) and Canter *et al.* (1992) referred to possible mutual ecological benefits of vorticellids-cyanobacteria interactions (i.e. buoyancy and feeding advantage for the attached vorticellids; protection of cyanobacteria from predators by the attached vorticellids).

The present study reports brief quantitative observations on the vorticellids-planktonic algae interactions in the Hawkesbury-Nepean River during the summer 1991 when a bloom of *Melosira* (diatom) and *Microcystis* (cyanobacterium) occurred. Although attachment of vorticellids to a wide range of planktonic cyanobacteria has been reported overseas, there is no comparative observation of their occurrence on a surface of cyanobacteria and other planktonic algae for Australia.

STUDY AREA

Detailed descriptions of the hydrology and morphology of the Hawkesbury-Nepean River are reported by State Pollution Control Commission (1983) and Heath and Cannon (1990). The Hawkesbury-Nepean River flows from the Illawarra range to its mouth north of Sydney. The main river channel length is approximately 300 km, with a total catchment area of 22000 km². The river flow is regulated by five major dams (Avon, Nepean, Cordeaux, Cataract and, further downstream, Warragamba) and over 13 weirs on its main channel. The tidal limit is near Richmond, about 140 km upstream of the river mouth (Wolanski and Collis, 1976). The river provides water for many uses

(e.g. potable water and irrigation) and supports commercial and recreational fishing (Department of Planning, 1989).

MATERIALS AND METHODS

Quantitative zooplankton samples were collected by using a Haney-type trap (4.2 l) (R. J. Shiel, pers. comm.) on 6 December 1991 at Windsor (0900-0930 hrs) and Sackville (1030-1100 hrs) where *Melosira* and *Microcystis* blooms were observed, respectively (Fig. 1). Four replicate samples were collected at approximately equal time intervals at a depth of 1 m at the mid channel. The trap was closed as soon as it reached the sampling depth. Samples were filtered in the field through a 35 μ m mesh net and the plankters retained on the net were backwashed into a 125 ml plastic jar and preserved in a 4% buffered sugar-formaldehyde solution (Haney and Hall, 1973). Zooplankton species were identified by using published keys and illustrations (Koste and Shiel, 1987; Smirnov and Timms, 1983). Mean zooplankton abundance (individuals l^{-1}) was calculated for each taxon by counting subsamples (400-600 individuals) with the Sedgewick-Rafter counting cell at 100x under a Nikon Diaphot-TMD inverted microscope. Proportion (%) and mean number of vorticellids attached to each substrate particle were calculated for a maximum of 100 vorticellids. Some free vorticellids which may have dislodged from substrate particles during transportation and preservation of samples (Kerr, 1983) were not included. Selectivity of the vorticellids for planktonic algae as a substrate particle was determined by calculating Ivlev's electivity index (Ivlev, 1961): $(p_i - p_a)/(p_i + p_a)$ where p_i is the proportion of a particular substrate particle to which vorticellids are attached and p_a is the proportion of that substrate particle free from vorticellid attachment in the water. The index ranges from a scale of -1 for total avoidance or inability to attach to nearly +1 if the planktonic alga is preferred by vorticellids as a substrate particle. No selection at all occurs at a scale of 0. Relative abundance of the phytoplankters free from vorticellid attachment was determined by counting approximately 500 individuals with the Sedgewick-Rafter counting cell (one colony or one filament was counted as one individual). Photomicrographs of the vorticellids occurring on the surface of planktonic algae were taken using a Nikon F-601M camera attached to the inverted microscope and Kodak px-125 film with an exposure time of 1/2s. Data on physico-chemical conditions (temperature, pH, dissolved oxygen, total phosphorus and chlorophyll *a*) at Windsor and Sackville on 26 November 1991 (closest to the zooplankton sampling date) were provided by AWT Science & Environment Division.

RESULTS

Physicochemical conditions

Both the Windsor and Sackville sites are characterized by relatively high pH, dissolved oxygen and chlorophyll *a*, reflecting the occurrence of algal blooms (Table 1).

Species composition and abundance of zooplankton

A total of 18 zooplankton taxa were identified at Windsor and Sackville (Table 2). Rotifers were the most diverse group, accounting for 72% of the total taxa. Numerically, protozoans were most important and were dominated by vorticellids at both Windsor (1623 l^{-1}) and Sackville (1766 l^{-1}). Of rotifers, *Keratella* (158 l^{-1} at Windsor) and *Trichocerca* (182 l^{-1} at Sackville) were relatively abundant. Copepods were abundant at Windsor, dominated by nauplii (321 l^{-1}). Cladocerans were a minor component or absent at Windsor and Sackville.

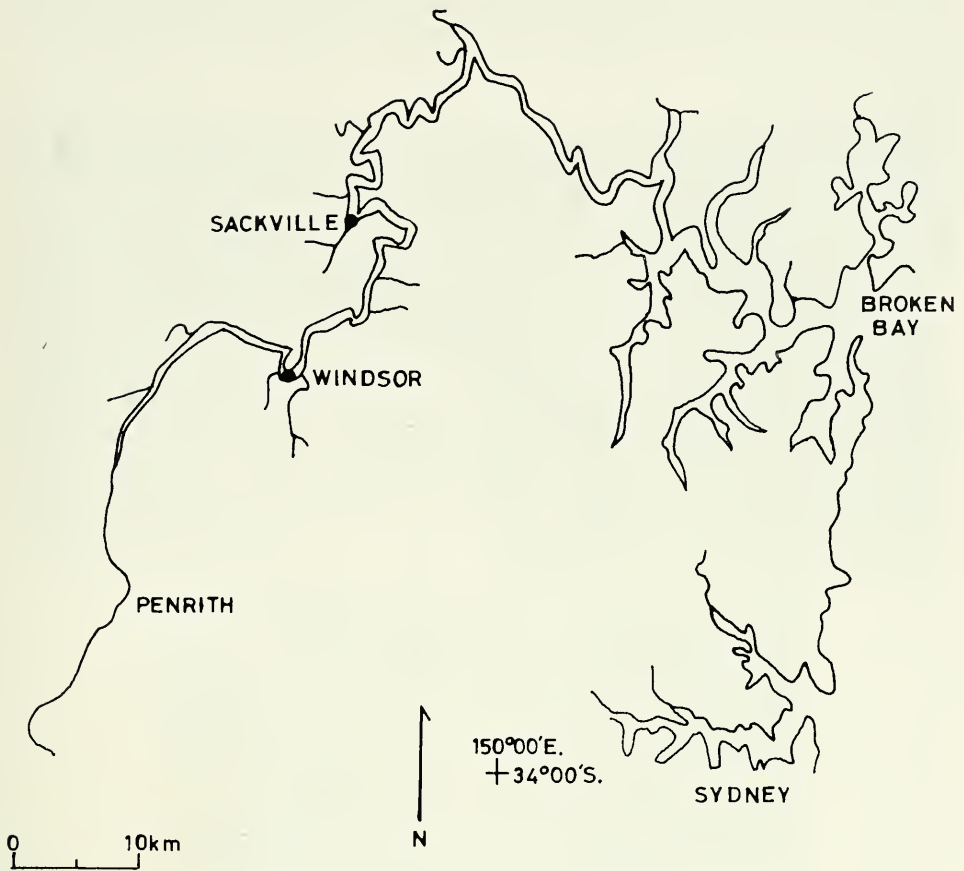


Fig. 1. Zooplankton sampling sites of the Hawkesbury-Nepean River.

TABLE 1

Physicochemical conditions and chlorophyll a at Windsor and Sackville in the Hawkesbury-Nepean River on 26 November 1991 (AWT Science & Environment Division, unpublished data)

| Parameters | Windsor | Sackville |
|---|---------|-----------|
| Time of measurement (summer time: hrs) | 0830 | 0930 |
| Temperature (°C) | 24.3 | 24.2 |
| pH | 7.3 | 8.9 |
| Dissolved oxygen (mg l ⁻¹) | 7.5 | 9.8 |
| Total phosphorus (mg l ⁻¹) | 0.062 | 0.046 |
| Chlorophyll a (µg l ⁻¹) | 26.7 | 33.5 |

Attachment of vorticellids to planktonic algae and detritus

Vorticellids attached to a total of nine planktonic algal taxa and detritus (Table 3 and Fig. 2). At Windsor, the vorticellids attached to the filamentous diatom *Melosira* and

colonial green alga *Volvox*. At Sackville, they attached to a variety of algal substrate particles including the cyanobacteria *Microcystis* and *Anabaena*. The mean number of vorticellids attached to each substrate particle was low in the range 1-3 at both sampling sites. A maximum of 11 vorticellids were observed on the surface of a single *Microcystis* colony at Sackville.

TABLE 2

Zooplankton in the Hawkesbury-Nepean River on 6 December 1991.

x denotes the presence of species

| <i>Zooplankton</i> | <i>Windsor</i> | <i>Sackville</i> |
|---|----------------|------------------|
| Protozoans | | |
| vorticellids | x | x |
| ciliates | x | x |
| Rotifers | | |
| <i>Brachionus angularis</i> Gosse | x | x |
| <i>Brachionus calyciflorus</i> Pallas | | x |
| <i>Brachionus calyciflorus anuraei</i> formis Brehm | x | x |
| <i>Brachionus falcatus</i> Zacharias | x | x |
| <i>Collotheca</i> sp. | x | x |
| <i>Conochilus dossuarius</i> Kauer | x | |
| <i>Filinia longiseta limnetica</i> (Zach.) | x | x |
| <i>Hexarthra intermedia</i> Wiszniewski | x | x |
| <i>Keratella cochlearis</i> (Gosse) | x | x |
| <i>Keratella tropica</i> (Apstein) | x | x |
| <i>Polyarthra</i> cf. <i>longiremis</i> (Carl.) | x | x |
| <i>Synchaeta pectinata</i> Ehrb. | x | |
| <i>Trichocerca</i> spp. | x | x |
| Gladocerans | | |
| <i>Bosmina meridionalis</i> Sars | x | |
| Copepods | | |
| nauplii | x | x |
| copepodites | x | x |

Vorticellids showed no particular selectivity for the major substrate particles, *Melosira* and *Microcystis* (Ivlev's index: 0.20 and 0.08, respectively) (Table 3). On the other hand, they appeared to prefer *Mougeotia* but avoid *Staurastrum* as a substrate particle because of the relatively high positive and negative values of the Ivlev's index (1.00 and -0.82), respectively.

DISCUSSION

This study is the first quantitatively describing the occurrence of vorticellids on a surface of cyanobacteria (*Anabaena* and *Microcystis*) and other planktonic algae in Australia, specifically the Hawkesbury-Nepean River. Attachment of vorticellids to various planktonic algae and other substrate particles is consistent with the observations of Kerr (1983) and Pratt and Rosen (1983). Although a species-specific association of vorticellids to cyanobacteria has been reported by Davis (1973) and Pratt and Rosen (1983), it was not possible to examine the degree of such an association in this study because no vorticellid species were identified. They, as a group, however, appear to exhibit no particular selectivity for cyanobacteria as a substrate particle in the Hawkesbury-Nepean River. Relative preference for and avoidance of *Mougeotia* and *Staurastrum*, respectively, at Sackville (as measured by the Ivlev's index) suggest that some factor(s) (e.g. cell or colony morphology and/or some nutritional or chemical

attractants of algae (Kerr, 1983; Canter *et al.*, 1992) may be responsible for the selectivity. Further detailed study is necessary to elucidate causal factors.

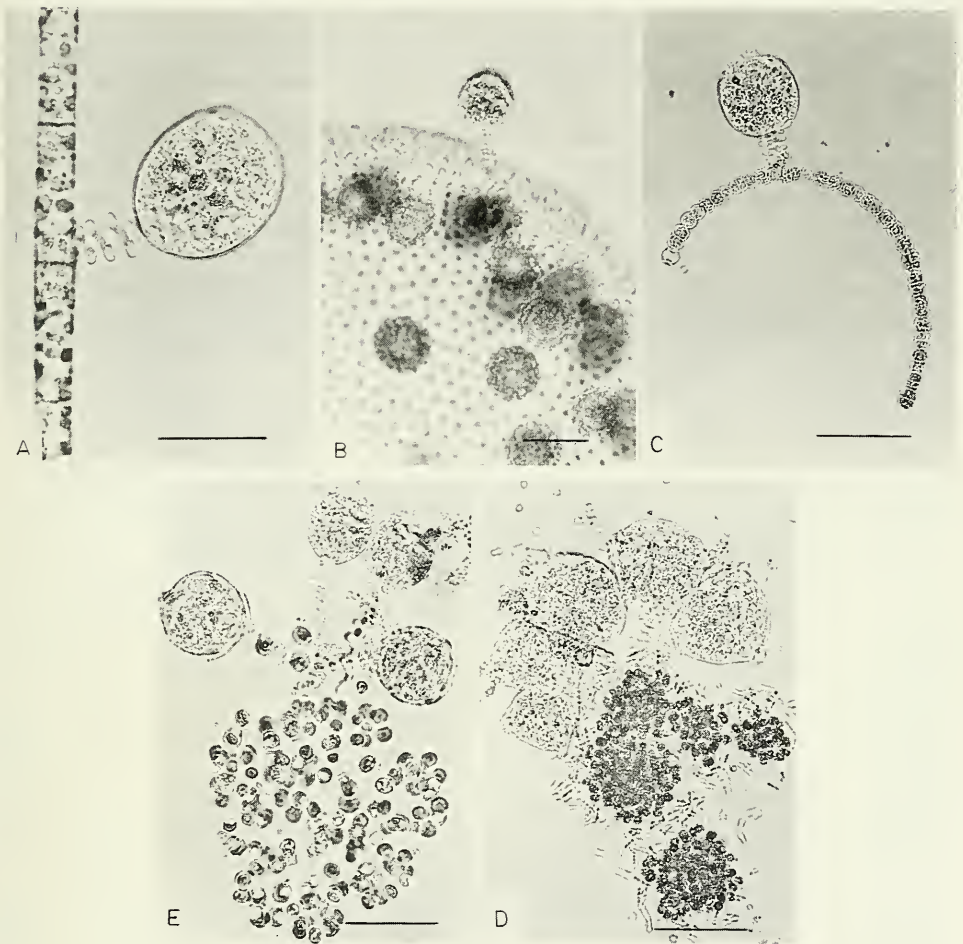


Fig. 2. Attachment of vorticellids to various planktonic algae at Windsor and Sackville in the Hawkesbury-Nepean River on 6 December 1991. Substrates as (a) *Melosira granulata*; (b) *Volvox*; (c) *Anabaena*; (d) *Microcystis cf. aeruginosa*; (e) *Dictyosphaerium*. Bars: 20 μm (A), 40 μm (B, C, D, E).

The number of vorticellids attached per algal substrate particle reported in the literature varies with algal taxa and morphology. Kerr (1983) reported that 68% of *Nostoc* colonies infested by *Vorticella* had 1-5 vorticellids but some had over 100 vorticellids, whereas *Anabaena* colonies had in most cases, fewer than five vorticellids. Pratt and Rosen (1983) found 35-50 attached vorticellids on a large colony of *Anabaena flos-aquae* but just one or two attached to individual filaments. In the Hawkesbury-Nepean River, the number of the vorticellids attached on the surface of an algal substrate particle remained low, irrespective of the algal type.

In general, the vorticellids-planktonic algae interactions may be classified as

commensalism, in which one population (i.e. vorticellids) is benefitted but the other (i.e. planktonic algae) is not affected, or as proto-cooperation, in which both populations benefit by the association but relations are not obligatory (definitions of commensalism and proto-cooperation as in Odum, 1971, p.211). The benefit to vorticellids of attaching to planktonic algae (particularly to buoyant cyanobacteria) is that vorticellids use these algae as a substrate to produce more effective feeding currents and remain in the food-rich water column for longer periods (Fenchel, 1987; Canter *et al.*, 1992). On the other hand, planktonic algae to which vorticellids are attached may gain protection against predators such as ciliates (Dryden and Wright, 1987) if the number of attached vorticellids is sufficiently large. Attached vorticellids are thought to provide a shielding effect, thus making it difficult for predators to find algae (Pratt and Rosen, 1983; Canter *et al.*, 1990). Furthermore, there may be nutrient exchange between vorticellids and planktonic algae, including dissolved organic and inorganic nutrients or epiphytic bacteria (Pratt and Rosen, 1983). Because of the scarcity of vorticellids attached per algal substrate particle in the present study, neither protection of planktonic algae against predators by the attached vorticellids nor active nutrient exchange between them is likely to occur. The observed vorticellids-planktonic algae interactions appear to be more commensal than proto-cooperative.

TABLE 3

Attachment of vorticellids to planktonic algae and detritus at Windsor and Sackville in the Hawkesbury-Nepean River at a depth of 1 m on 6 December 1991. A: Proportion (%) of attachment of vorticellids (n=100) to each substrate. + denotes < 1%. B: Number of vorticellids attached to a colony or filament of each substrate. Mean \pm SE is shown. Sample size is given in parentheses. C: Ivlev's electivity index for each algal substrate

| Substrate | Windsor | | | Sackville | | |
|---|---------|---------------------|------|-----------|--------------------|-------|
| | A | B | C | A | B | C |
| Cyanobacteria | | | | | | |
| <i>Anabaena</i> sp. | — | — | — | 3 | 1.3 \pm 0.25(4) | 0.14 |
| <i>Microcystis</i> spp. | — | — | — | 52 | 3.0 \pm 0.36(59) | 0.08 |
| Diatoms | | | | | | |
| <i>Melosira</i> spp. (mainly <i>granulata</i>) | 100 | 1.4 \pm 0.09(100) | 0.20 | 4 | 2.0 \pm 0.99(2) | 0.43 |
| Green algae | | | | | | |
| <i>Dictyosphaerium</i> sp. | — | — | — | 13 | 1.3 \pm 0.21(15) | 0.33 |
| <i>Micrasterias</i> sp. | — | — | — | + | 1.5 \pm 0.50(2) | — |
| <i>Mougeotia</i> sp. | — | — | — | 5 | 2.2 \pm 0.63(10) | 1.00 |
| <i>Staurastrum</i> sp. | — | — | — | 1 | 1(1) | -0.82 |
| <i>Volvox</i> sp. | + | 1(1) | — | — | — | — |
| Unidentified alga | — | — | — | 2 | 1.5 \pm 1.06(2) | — |
| Detritus | — | — | — | 20 | 2.2 \pm 0.50(30) | — |

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